Recovery of species diversity after disturbance of broad-leaved Korean pine mixed forest in Changbai Mountain[1]

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Abstract Recovery of species diversity after catastrophic disturbance was influenced by a few factors, such as intensity of disturbance, availability of propagules, and the environmental conditions. In this paper, we examined patterns of species development after nearly 60a succession in burned broad-leaved Korean pine mixed forest on northern slope of Changbai Mountain. We assessed the recovery of plant species diversity in 3 types of forests under the condition with gradient of soil moisture. Results revealed that recovery of plant species diversity varied greatly under different environmental conditions. Species richness of secondary forests greatly related to the site condition. Secondary birch forest on mesic site had the greatest number of plant species and the following was poplar-birch forest and larch-birch forest. Most of characteristic taxa could be found in birch forest after 60a succession. For larch-birch forest on hydra site, most of climax species were still not able to invade, so it had the lowest species diversity.

Key words: Recovery, Broad-leaved Korean pine mixed forest, Environmental conditions, Species diversity.

Introduction

More recently, The human has showed a great interest in studies on patterns of changes in species diversity during process of succession. The disturbance of human activities or nature disasters has a great impact on species diversity. Plant species comprising a post-disturbance community derive from a variety of sources—wind dispersed seed, buried propagules and resprouting survivors [1, 4]. Their ultimate contribution to the serial flora reflects a complex interaction of initial abundance, including disturbance intensity, propagate availability, and chance. Consequently, when ecosystem is subjected to heterogeneous disturbance in large-scale, species diversity commonly follows multiple to be recovered [2, 3].

In Changbai Mountain area, the broad-leaved Korean pine mixed forest is a major type of forest. Majorities of virginally forest cover lower elevation area. Compared with vegetation of Europe and North America in the same latitude, this type of forest is significant for its complex composition and structure, high biodiversity, and specific dominant species[7, 8]. However, at lower elevation area where human's disturbance is very severe, secondary forests have replaced most of this type of forest during the past 100a. The area of virgin forests has decreased dramatically, from about 30 millions hm^2 at the end of 18th centenary to only about 1 million hm^2 [6]. Virgin forests now only can be found in National Reserve of Changbai Mountain and some remote area. The patterns of species diversity have changed greatly. Many species, which closely depend on the existence of broad-leaved Korean pine mixed forests, were disappeared. These species included not only some of narrow-distributed plant species but also some of vertebrates and aquatic species[6].

In this paper, we presented data from one plot of virgin broad-leaved Korean pine mixed forest and three plots of secondary birch forest in the National Reserve of Changbai Mountain. The major purpose was to assess the effect of environmental condition on recovering plant population among 3 secondary forest types and virgin broad-leaved Korean pine forest from different drainability of soil condition.

Methods and study area

Changbai Mountain is one of the valuable reserves for its various natural ecosystems and rich gene pool, especially for the latitudinal vegetation zonation in the mountain, which are typical representatives of northeastern Asian forests. There are 4 vegetation zones from lower to higher elevations. The broad-leaved Korean pine mixed forest distributed below altitude of 1100 m is the most diversified forest in species. Four sample plots in this research were located within this zone[8].

The climatic characteristics in this zone are of cold weather during the long winter and short cool summer. The mean temperature ranges from -18°C in January to 18°C in July. The accumulated temperature above 10°C is about 1500°C. The annual precipitation is 700 ~ 800 mm and frost-free period is 100~120d. The soil type is the Montana dark-brown forest soil[9].

Four sample plots were located within National Reserve of Changbai Mountain. Three plots of secondary birch

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forest were adjacent to the virgin broad-leaved. Korean pine mixed forest, so all of them had the sources of propagules of virgin forest species. Secondary forests were developed after the fire in 1939 and without further disturbance then. They were the same in disturbance intensity, propagule availability, and the period of succession. The significant difference among 3 secondary birch forests was environmental conditions, especially the drainability of soil. The basic status of study area was listed in Table 1.

Table 1. Basic status of study area (1 600 m²)

Forest type	Altitude /m	Slope /degree	Age of dominant tree /a	Soil moisture* (Jun.~Sept.) %	Soil type	Site condition
A (Broad-leaved Korean pine forest)	740	5	190	82.4	typical dark brown soil	Mesic
B_1 (Polar-birch Forest)	750	5	55	85.7	typical dark	Mesic-xeric
B_2 (Birch forest)	730	3	55	92.6	brown soil typical dark	Mesic
B_3 (Larch-birch Forest)	710	2	55	137.8	brown soil drag turf	hydra

Note: *The data was adopted from Xu Guangshan (1980)

A sample plot (40 m × 40 m) was estimated in the woody plant diversity for both virgin forest and secondary forests after drawing the species/area curve. For herb, 50 subsumable plots (1 m × 1 m) were randomly investigated. For trees, we recorded the species, diameter (≥4 cm) and height individually. For shrub and herb, we recorded their numbers of individuals and height. The fieldwork was carried out in the growing season of 1993 and 1994.

Species diversity (H') and evenness (E) were calculated in each of the plots to be obtained the Shannon index:

$H=-\Sigma(P_i \cdot \ln P_i)$, and $E=H'/\ln(S)$[5].

Where, P_i is the proportional abundance of i th species, given by $P_i=n_i/N$. $i=1,2,3,...S$; n_i is the number of individuals of the ith species and N is the known total number of individuals for all species (S) [5].

Results and analysis

Tree species diversity

Richness and diversity of tree species were calculated from overstory (D>12 cm), successional story (4 cm≤D≤12 cm) to under-story (D<4 cm) respectively. Richness and diversity of tree species for virgin broad-leaved Korean pine mixed forest and 3 secondary birch forests were listed in Table 2 to 5.

From Table 2, 3 and 4, we could see that species number, and diversity index of forest B_1 and B_2 was larger than that of broad-leaved Korean pine mixed forest. The dominant tree species of broad-leaved Korean pine mixed forest, such as *Pinus koraiensis, Tilia amurensis, Acer mono, Fraxinus mandshurica, Quercus mongolica* were nearly developed in different layers. Individuals of these five characteristic species took a percentage of 8, 54.4, and 69.8 on over-story, successional story and under-story in forest B_1 respectively, and percentage of 3.9, 42.9, and 55.3 in forest B_2.

Table 2. Species diversity of different tree layers of broad-leaved Korean pine forest (A)

Tree Species	Layers (DBH) >12 cm NI	RA %	4~12 cm NI	RA %	<4 cm NI	RA %
Pinus koraiensis	43	47.3	6	20.7		
Tilia amurensis	13	14.3	2	6.9	1	1.1
Acer mono	17	18.7	3	10.3	31	34.8
Fraxinus mandshurica	7	7.7	2	6.9	1	1.1
Quercus mongolica	5	5.5			3	3.4
Phellodendron amurense	2	2.2				
Abies holophylla	1	1.1				
Ulmus japonica	1	1.1				
Tilia mandshurica			1	3.4	2	2.2
Acer pseudo-siebodianum	3	3.3	15	51.7	23	25.8
Maackia amurensis					19	21.3
Acer tegmentosum					1	1.1
Malus baccata					1	1.1
Syringa reticulata					2	2.2
Number of species					15	
S in different layer	9		6		11	
Number of individuals	92		29		89	
Shannon index	1.5483		1.3866		1.6950	
Shannon evenness	0.7449		0.7752		0.7071	

Notes: NI-Number of individuals, RA-Relative abundance (%)

This was because that the forest B_1 and B_2 were growing on soil with drainage and high nutrient. The short life span of pioneer species lead to a rapid replacement of species. Meanwhile, the age of two types of forests was nearly 60a old and just in the mid-stage of succession. Since they were adjacent to the virgin forest. And propagules of taxa were available, nearly all the climax species could be found in both of forests, and some of them have grown up to the canopy. These two forests had pioneer species and climax species at the same time [9]. After then, climax species gradually grew up to have the canopy and replaced the pioneer species so that the species diversity

began to decrease.

Table 3. Species diversity of different tree layers of secondary Poplar-birch forest (B_1)

Tree species	>12 cm		4~12 cm		<4 cm	
	NI	RA %	NI	RA %	NI	RA %
Pinus koraiensis					62	5.7
Tilia amurensis	5	5.7	45	22.1	85	7.8
Acer mono			36	17.6	500	46.0
Fraxinus mandshurica	2	2.3	2	1.0	5	0.5
Quercus mongolica			28	13.7	106	9.8
Phellodendron amurense	3	3.5	5	2.5	3	0.3
Ulmus japonica	4	4.6	17	8.3	56	5.2
Populus davidiana	27	31.0	11	5.4	1	0.1
Betula platyphylla	42	48.3	13	6.4		
Larix olgensis	1	1.2	1	0.5		
Picea koraiensis			1	0.5	1	0.1
Betula davurica	2	2.3				
Acer pseudo-siebodianum					82	7.6
Maackia amurensis	1	1.2	11	5.4	39	3.6
Acer tegmentosum					1	0.1
Malus baccata			28	13.7	100	9.2
Syringa reticulata					6	6.1
Salix raddeana			1	0.5		
Padus maackii			2	1.0		
Acer triflorum			3	1.5	29	2.6
Padus asiatica					4	0.4
Cerasus maximowiczii					1	0.1
Micromeles alnifolia					1	0.1
Sorbus pohuashanensis					4	0.4
Number of species(S)						24
S in different layers	9		15		19	
Number of individuals	87		204		1086	
Shannon index	1.4127		2.2040		1.8741	
Shannon evenness	0.6433		0.8140		0.6365	

Notes: NI-Number of individuals, RA-Relative abundance (%)

General pattern of tree species diversity in this situation was relatively high at the beginning, then species increased from early succession to mid-succession. Middle stage could last for nearly hundred years, and then diversity decreased in late succession as climax species replaced the pioneer species completely and came to dominant.

In forest B_3 with poor drainage and nutrient soil formed a poor site condition for tree species. Although birch and a few other species, such as larch, could survive in this kind of bad drainage condition. Most of climax species were not able to colonize so that species diversity was still very low after nearly 60a succession. Individuals of five characteristic species only took a percentage of 0, 5.4 and 31.6 on over-story, successional story and under-story respectively. In this situation, The speed of the species replacement and succession was very slow, even though the seed source of climax species was available. In Changbai Mountain area, this kind of site had the lowest species diversity and the lowest succession speed among the secondary forests.

Table 4. Species diversity of different tree layers of secondary birch forest (B_2)

Tree species	>12 cm		4~12 cm		<4 m	
	NI	RA %	NI	RA %	NI	RA %
Pinus koraiensis	4	3.1	48	15.6	154.0	44.6
Tilia amurensis	1	0.8	83	27.0	25.0	7.2
Acer mono			1	0.3	5.0	1.5
Fraxinus mandshurica					7.0	2.0
Phellodendron amurense			2	0.7		
Abies nephrolepis	1	0.8	21	6.8	51.0	14.8
Populus davidiana	4	3.1	2	0.7	3.0	0.9
Betula platyphylla	97	74.6	63.0	20.5	1.0	0.3
Larix olgensis	13	10.0	25.0	8.1	1.0	0.3
Picea koraiensis	10	7.7	62.0	20.2	27.0	7.8
Acer pseudo-siebodianum					7.0	2.0
Acer tegmentosum					51.0	14.8
Acer mandshuricum					1.0	0.3
Ulmus laciniata					1.0	0.3
Padus asiatica					2.0	0.6
Sorbus pohuashanensis					6.0	1.7
Betula costata					1.0	0.3
Acer ukurunduense					2.0	0.6
Number of species (S)					18	
S in different layers	7		9		17	
Number of individuals	130		307		345	
Shannon index	0.9352		1.7638		1.7905	
Shannon evenness	0.4807		0.8027		0.6320	

Notes: NI-Number of individuals, RA-Relative abundance (%)

Table 5. Species diversity of different tree layers of secondary larch-birch forest (B_3)

Tree species	>12 cm		4~12 cm		<4 cm	
	NI	RA %	NI	RA %	NI	RA %
Acer mono			7	5.5	6	31.6
Populus davidiana	4	2.5	1	0.8	7	36.8
Betula platyphylla	93	57.8	53	41.4		
Larix olgensis	26	16.2	58	45.3		
Maackia amurensis			1	0.8		
Alnus hirsuta	37	23.0	8	6.3		
Ulmus laciniata					1	5.3
Malus baccata					1	5.3
Salix raddeana	1	0.6				
Cerasus maximowiczii					4	21.1
Number of species (S)					11	
S in different layers	5		6		5	
Number of individuals	161		128		19	
Shannon index	1.0728		1.1318		1.3699	
Shannon evenness	0.6666		0.6318		0.8543	

Notes: NI-Number of individuals, RA-Relative abundance (%)

Species diversity of shrub

Species diversity of shrub for 4 types of forests was listed in Table 6.

Table 6. Species diversity of shrub in forests (1600 m^2)

Type of forest	Number of species	Shannon index	Shannon evenness
A Broad-leaved Korean pine mixed forest	21	2.1610	0.7098
B_1 Birch forest	22	2.5316	0.8190
B_2 Poplar-birch forest	16	2.1702	0.7827
B_3 Larch-birch forest	9	0.8539	0.3886

For shrub, plant species diversity of forest B_1 was the highest among 3 secondary forests and even higher than that of virgin broad-leaved Korean pine forest. Forest B_3 was the lowest in diversity index and evenness. The dominant species of both B_1 and B_2 were very similar to that of virgin forest. But in forest B_3, the dominant species was different from that of A, B_1 and B_2. Instead of *Corylus mandshurica* and *Philadelphus schrenkii* which were the dominant species of forest A, B_1 and B_2, the rate of *Spiraea salicifolia, Rubus crataegifolius,* and *Lonicera maximowiczii* took 90% of total individuals in forest B_3. The evenness was only 0.3886.

Species diversity of herb

Species diversity of herb for 4 types of forests was listed in Table 7.

Table 7. Species diversity of herb in different forests (50 plots of 1 m × 1 m)

Type of forest	Season of Survey	Number of species	Number of genera	Number of family	Average of species /m^2
A Broad-leaved Korean pine Forest	May	79	65	29	20±5.6
	June ~ July	101	85	42	15±3.6
	August ~ Sep.	98	82	42	11±2.7
B_1 Birch forest	May	73	61	28	13.7±5.5
	June ~ July	88	78	38	14.5±3.8
	August ~ Sep.	83	71	35	13.5±3.5
B_2 Poplar-birch forest	June ~ July	79	66	31	13.4±4.7
B_3 Larch-birch forest	June ~ July	37	31	22	7.3±4.8

The result showed that the virgin forest A was the highest on number of species, genera, family and species in per square meter among 4 types of forests, and the following is forest B_1, B_2 and B_3. Not only the number of species, but also the evenness and composition of species were very different among 4 types of forests. The herb story of virgin forest was dominated by many species, which closely depended on old-growth forest environment. But the herb species diversity was highest in secondary forests, even in forest B_1 among the secondary forests, only a few species were dominant species and these species were mostly wide-distributed species like *Carex* Spp.

The species richness of forest B_1 was very close to that of forest A, but species in per square meter at early spring was very different. This index of forest A is much higher than that of forest B_1. In early spring, the dominant species of virgin forest are mainly early spring plants, which finish their life history at early spring before sprout of tree leaves, such as *Anemone* Spp, *Corydalis* Spp, *Gagea* Spp, etc. On the other hand, the dominant herb species of birch forest in early spring are chiefly *Carex* Spp. The early spring plants only take a small percentage. In forest B_3, there are only 37 species of herb and most of these species are water-like species. *Carex* took 90% of total individuals.

Conclusions and discussion

After the virgin broad-leaved Korean pine forest was destroyed, the secondary succession began on the burned area. As a result of succession, secondary forests with different structure and composition developed under different environmental conditions. When the propagules are available, environmental condition under which succession occurs determines the rate and extent of recovery. In the Changbai Mountain, the drainability of soil is a key factor to determine the recovery of species diversity.

Most of plant species can be recovered under mesic condition well after nearly 60a in secondary succession, nearly all the tree species of virgin forest can be found in this secondary birch forest. The woody plant species diversity of Poplar-birch forest on mesic-xeric condition is little lower than that of birch forest on mesic site. It is very hard for most of woody plant species of virgin forest to recover under the hydra conditions. Only a few species can be survival on the waterlogging site.

Compared with tree species, it is not able for the effect of environmental condition to recover under-story species diversity. It needs a long period to recover from the disturbance for under-story species. The herb diversity is great difference among 3 secondary forests. In forest B_3, the drainability of soil is very poor, there are only 37 species of herb recorded in the summer, and only 30% of virgin forest and half of birch forest on mesic condition.

Not only the diversity of herb species in secondary forests decreases, but also abundance distribution is uneven. Herb story is mainly occupied by some of common species, such as *Carex* Spp. Many peculiar or rare species of broad-leaved Korean pine forest are very few and some

species are even vanished completely in secondary forest. This phenomenon is clearer for early spring plants.

The study on diversity of plant species in secondary birch forest indicated clearly that it is possible to recover naturally if there are only seed source and without further disturbance. But it takes a long time to recover.

In Changbai Mountain area, the patterns of changes in species diversity during the secondary succession process are very complicated because of the variation of environmental condition and human's activities. Species diversity can have a great potentiality to recover as long as disturbance area is not too large and the disturbance frequency is not too high. The rate and extent of recovery are determined by the environmental condition greatly.

References

1. Halpern, C. B., Franklin J. F. 1987. Under-story development in Pseudotuga forest: Multiple paths of succession. Poster presented at Symposium on Land Classification Based on Vegetation : Applications for Resources Management, Moscow, Nov. 17~19, 293~297.
2. Halpern, C. B., Franklin J. F., and Mckee A. 1992a. Changes in plant species diversity after harvest of Douglas-fir forests. Journal of Northwest Environment. 8: 205~207.
3. Halpern, C. B., Antos J. A., Cromack K.etc. 1992b. Specie's interactions and plant diversity during secondary succession. Journal of Northwest Environment. 8: 203~205.
4. Hustan, M. A. 1994. Biological Diversity: The coexistence of species on changing landscapes. Cambridge University Press
5. Maguran, A. E. 1988. The Ecological diversity and its measurement. Princeton University Press.
6. Chen Linzi. 1993. Biodiversity in China—Present Situation and Conservation Strategy. Beijing. Science Press. pp 121 (in Chinese).
7. Hao Zhanqing, Tao Dali, Zhao Shidong. 1994. Diversity of higher plants in broad-leaved Korean pine and secondary birch forests on northern slope of Changbai Mountain. Chinese Journal of Applied Ecology. (5) : 16~23 (in Chinese).
8. Wang Zhan, Xu Zhenbang et al. 1980. The main forest types and their features of community-structure in northern slope of Changbai Mountain (1). In: Research of Forest Ecosystem Vol. 1 (eds:Changbai Mountain Research Station of Forest Ecosystem). 25~42 (in Chinese).
9. Xu Guangshan, Ding Guifang et al. 1980. A primary study on soil humus and its characteristics in the main forest types on northern slope of Changbai Mountain (1). In: Research of Forest Ecosystem Vol. 1 (eds:Changbai Mountain Research Station of Forest Ecosystem). 215~200 (in Chinese).

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